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KENNETH A. BRINKMAN began his Forest Service career at the Central States Station 20 years ago. He soon moved to Mississippi with the Southern Forest Experiment Station, then to Arizona with the Southwestern Station, then to Alabama with the Southern Station again. Finally, in 1948, he returned to the Central States and worked in Iowa until 1955. Since then he has been at our research center at Columbia, Missouri. A lieutenant in the Coast Guard during World War II, Brinkman was commanding officer of a subchaser and later a tanker. Ken got his forestry training in his native state of Iowa, earning B.S. and M.S. degrees at Iowa State University. He is a silviculturist specializing in regeneration, woody-plant control, and conversion of low-quality oak stands.

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Mixed or Pure Walnut Plantings on Strip-Mined Land in Kansas?

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Because of its high potential value, black walnut *(Juglans nigra* L.) has been extensively planted on strip-mined land in southeastern Kansas and elsewhere. Experience in other areas has indicated that walnut grown on spoil banks in pure stands generally is inferior to trees grown in mixture with other species [1, 2]. A study begun in 1950 in Cherokee County, Kansas, to compare the growth and quality of walnut grown in pure and mixed stands, shows the need for choosing the right species for planting with walnut.

The study area was stripped for coal in 1946. About 25 feet of overburden was removed and piled in long east-west ridges about 20 feet high and 80 feet apart (fig. 1). The bank material is a shaly, loose clay with pH about 7.5 and few toxic acid spots. At the time of planting in 1950 the area was relatively free of vegetation, but erosion and silting-in of the valleys had already begun.

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[1]Boyce, Stephen G., and Merz, Robert W. Tree species recommended for strip-mine plantations in western Kentucky. U.S. Dept. Agr., Forest Serv., Cent. States Forest Expt. Sta. Tech. Paper 160, 12 pp., illus. 1959.

[2]Deitschman, Glenn H., and Lane, Richard D. Forest planting possibilities on Indiana coal-stripped lands. U.S. Dept. Agr., Forest Serv., Cent. States Forest Expt. Sta. Tech. Paper 131, 57 pp., illus. 1952.

The survival, growth, and form of walnut in pure stands were compared with those of walnut grown in mixture with black locust *(Robinia pseudoacacia* L.*),* bur oak *(Quercus macrocarpa* Michx.*),* eastern redcedar *(Juniperus virginiana* L.*),* sycamore *(Platanus occidentalis* L.*),* and green ash *(Fraxinus pennsylvanica* Marsh.*).* The planting materials consisted of stratified walnut seed, 2-0 bur oak seedlings, and 1-0 locust, sycamore, ash, and redcedar.

Five different kinds of plantings were compared:

- 100 percent walnut
- 75 percent walnut, 25 percent locust
- 50 percent walnut, 50 percent locust
- 10 percent walnut, 50 percent locust, and 10 percent each of bur oak, sycamore, green ash, and redcedar.
- 20 percent walnut, no locust, and 20 percent each of the other four species.

Where possible each species was planted in a row by itself, with the rows running across contours so that the effect of north and south aspects, ridges, and valleys could be observed. A 7- by 7-foot spacing was used. Four replications of each planting were provided, with random assignment

FIGURE 1. — Spoil banks of study area just before planting in 1950, 4 years after stripping. The bank material is a loose, shaly clay. Natural vegetation is weeds and prairie grasses.

of plots within blocks. In the spring of 1951 "failed" seed spots of walnut were planted with 1-0 walnut seedlings; missing locust and redcedar were replanted with 1-0 stock.

After 10 growing seasons, the spoil banks were adequately stocked with trees (fig. 2). Observations and measurements on individual trees included survival, total height, and form, as well as any apparent reason for failure or damage. Soil samples were collected from some plots containing locust and from some without locust and analyzed for total nitrogen. Form was classified as follows:

(1) *Good* — A tree with a single strong leader, straight stem, and reasonably good potential to make a merchantable tree.

(2) *Poor* — A tree without main leader, crooked, branchy, or leaning.

(3) *Fair* — A tree not classified as good or poor.

Cattle grazed the study area for the 5 years preceding this report. This was unfortunate because some trees were damaged by browsing, but it illustrates the differences in palatability of these species when severely overgrazed. Bur oak was most heavily damaged; any tree within reach of the cattle was eaten back almost to the ground each year. Damage to black walnut and green ash was not as extensive or serious as on bur oak. Rabbits and woodchucks also browsed these three species. All trees showing evidence of animal damage were excluded from comparisons of height growth and form.

FIGURE 2. — Spoil banks in 1960, 10 years after planting. Trees in foreground are black walnut; those in background are black locust.

Black Walnut Grew Best Without Black Locust

Survival of the walnut was best in pure stands but nearly as good in mixtures not containing locust (table 1). Where locust comprised 25 percent of the stand, walnut survival was about 10 percent less. And in mixtures containing 50 percent locust survival of the walnut was significantly lower.

Height growth of the walnut was about the same in all species combinations studied. Walnut was tallest in pure stands, but there were no significant differences in the heights of the walnut among any of the mixtures tested. The average height was about 7.5 feet.

Form and potential value of walnut were much lower in the mixtures containing locust. Walnut in pure stands had the best form (fig. 3). The three mixtures containing locust had about twice as many poorly formed trees as those without locust (fig. 4) (table 2). The absence of a strong leader is attributed to overtopping by the locust. Even though the locust overstory eventually dies or is cut, such poorly formed walnut trees seldom will develop into high-quality sawlogs.

FIGURE 3. — (Left) Most black walnut in the pure planting had good form.

FIGURE 4. — (Below) Black walnut showed poor form in a walnut-locust mixture because of severe competition. Note accumulation of locust litter.

TABLE 1. — *Survival of planted trees after 10 years*
(In percent)

Species mixture (Percent)	Black walnut	Black locust	Bur oak	Green ash	Eastern redcedar	Sycamore
Walnut — 100	83	....	....	....	....	....
Walnut — 50 Locust — 50	59	66	....	....	....	....
Walnut — 75 Locust — 25	73	85	....	....	....	....
Walnut — 10 Locust — 50 Ash — 10 Redcedar — 10 Oak — 10 Sycamore — 10	60	76	[1]59	94	43	5
Walnut — 20 Ash — 20 Redcedar — 20 Oak — 20 Sycamore — 20	79	....	[1]55	94	56	62

[1]Survival probably affected by cattle grazing.

TABLE 2. — *Walnut and locust tree form after 10 years*
(In percent)

Species mixture (Percent)	Walnut form			Locust form		
	Good	Fair	Poor	Good	Fair	Poor
Walnut — 100	38	36	26	....	....	....
Walnut — 50 Locust — 50	23	31	46	14	34	52
Walnut — 75 Locust — 25	15	32	53	12	40	48
Walnut — 10 Locust — 50 Ash — 10 Redcedar — 10 Oak — 10 Sycamore — 10	9	37	54	13	38	49
Walnut — 20 Ash — 20 Redcedar — 20 Oak — 20 Sycamore — 20	30	43	27	....	....	....

Performance of Other Species

Black locust had good survival (table 1) and was tallest of the six species at the end of 10 years. The trees were about 23 feet high. Aspect and topography had very little effect on survival and height growth, the north slopes being only slightly more favorable than the ridges and south slopes. Regardless of species mixture, about half the locust trees have poor form and only about 12 percent are potential poles (table 2). Sprouting is excessive with most of the poorly formed trees having multiple stems (fig. 5). No damage from the locust borer *(Megacyllene robiniae* Forst.*)* was observed.

Bur oak was damaged so heavily by cattle that survival and growth data are not reliable. Many of the trees are only 1 or 2 feet tall because the leaders were browsed repeatedly. About 96 percent of the poor form of bur oak is attributed to grazing. However, individual trees that were not damaged show good height growth and form (fig. 6) here and in other plantings in this general area. This species has a better potential on spoil banks than indicated by this study.

Green ash had better survival than any other species: 94 percent of all planted trees were still alive after 10 years (table 1). In spite of grazing damage and competition from other species, particularly locust, the trees average nearly 12 feet in height. The mixture containing black locust has 11 percent more poorly formed ash trees than the mixture without locust (fig. 7).

FIGURE 5. — Most black locust had poor form with many branches and multiple stems.

FIGURE 6. — Undamaged bur oak showed good height growth and form.

FIGURE 7. — Most green ash were crooked with many branches and low potential for sawlogs, even in mixtures not containing black locust.

FIGURE 8. — Sycamore and redcedar planted in mixtures without black locust made excellent height growth and showed good form.

Eastern redcedar was heavily damaged by locust competition here and in other areas.[3] Redcedar grown in mixed stands without black locust had 13 percent better survival and grew 50 percent faster than where locust was present. The difference in form of the redcedar grown with and without locust is striking. In the locust mixture only 6 percent of the cedar has good form as compared with 62 percent in the mixture without locust (fig. 8). About 60 percent of the poorly formed trees in stands containing locust were infested with bagworm *(Thridopteryx ephemeraeformis* Haw.*)* but overstory competition also affected form. The redcedar in the locust mixture is less vigorous and has poorer color for Christmas trees than that growing without locust.

Sycamore, an intolerant species, is severely affected by locust competition. Boyce and Merz found less than 2 percent survival of sycamore planted in mixtures containing 50 percent or more locust[1]. In this Kansas study only 5 percent of the sycamore survived when planted with locust as compared with 62 percent in the mixture without locust (table 1). Nearly half of the sycamore trees have good form (fig. 8), and some trees are more than 40 feet tall after 10 years.

[3]Limstrom, G. A. Forestation of strip-mined land in the Central States. U.S. Dept. Agr., Forest Serv., Agr. Hdbk. 166, 74 pp., illus. 1960.

Discussion

Locust is not recommended for planting in this area in mixture with other species because it persists too long in the stands. In other areas, where severe infestation of the locust borer assures early breakup of the locust, a mixture containing from 10 to 25 percent locust with walnut has been successful. However, this early stand breakup apparently cannot be relied upon in southeast Kansas. Although the locust probably improves soil structure and porosity, the severe competition offered by this fast-growing species seems to offset its beneficial effects in mixed plantings.

In southeastern Kansas frequent summer droughts interspersed with heavy downpours accentuate the detrimental effect of black locust on associated black walnut and other species beyond that observed in areas farther east where spring and summer precipitation are better distributed. The fast-growing, wide-spreading root system of the locust absorbs much of the available soil moisture. This, plus its rapid early height growth, gives the locust a decided advantage over walnut or other slower growing species.

The ability of locust to spread rapidly by means of root suckers is another argument against planting this species in the area. Even where a stand contains only 10 percent locust, these trees soon invade adjoining areas. Under some conditions, of course, this may be beneficial, but not in the walnut plantings studied.

A good layer of litter and duff has accumulated under most locust stands (fig. 4), while the ground still is nearly bare in those stands without locust. Soil aeration and water infiltration no doubt were improved by the locust litter, but the amount of total nitrogen in the soil was about the same in both kinds of stands.

Although pure stands of walnut were found to have the best survival, growth, and form 10 years after establishment, mixed plantings offer advantages such as the early harvest of fence posts and other products and more rapid site improvement which compensate for any apparent initial advantage of pure stands. Of the species studied, redcedar, bur oak, sycamore, and green ash seem best suited for interplanting with walnut on spoil banks of this area.

In general, the north slopes and valleys were the best planting sites for walnut and most other species, while the south slopes and ridges were the poorest. Cattle must be excluded from such plantings to avoid injury to the trees. This is especially true where bur oak is planted because this species is heavily damaged by livestock grazing.

Redcedar grew well and has an early market for Christmas trees and fence posts. When not damaged by grazing, bur oak grew almost as fast as walnut in this area. Sycamore showed excellent form and made good height growth but could overtop walnut on some sites. Although green ash had the best survival of any species tested, many trees are too crooked to produce merchantable logs. This species probably should be considered useful mainly as a nurse crop for the walnut. Thus, this study indicates that a practical mixture would consist of equal amounts of black walnut, bur oak, sycamore, and either redcedar or green ash.

Summary

Ten years after planting pure stands of black walnut were found to have better survival, greater height, and better form than walnut grown in mixture with black locust. In mixed stands without black locust, however, the walnut grew almost as well as in pure stands. Mixed plantings are recommended because they usually result in earlier harvest of merchantable products and faster improvement of site.

Even when comprising only 25 percent of a mixture, locust had a definite detrimental effect on walnut. A 50 percent locust component in the stand also reduced survival and growth of redcedar, green ash, bur oak, and sycamore.

On the basis of this study, black walnut should be planted with bur oak, sycamore, redcedar, or green ash on spoil banks in southeastern Kansas. A logical mixture might consist of equal amounts of the selected species.

Agriculture — Forest Service — Columbus, Ohio

The Central States Forest Experiment Station is headquartered at Columbus, Ohio and maintains major field offices at:

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